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ELECTRIC MOTOR STUDY TO DETERMINE THE OPTIMUM METHOD FOR REDUCING ELECTRICAL ENERGY COMSUMPTION AT LONE STAR ARMY AMMUNITION PLANT

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A large part of the cost of electricity at Lone Star Army Ammunition Plant (LSAAP) is attributable to the operation of electric motors used in the process operations. An electric motor study was conducted to determine the optimum method for reducing electrical energy consumption at LSAAP over the life-cycle of the equipment.

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20. ABSTRACT (cont)

An inventory was performed of all motors rated one-quarter horsepower and above. Of the 3566 motors inventoried, 1299 were active and 2267 were inactive. It was determined that the current electric motor replacement method is the most cost-effective and energy-efficient over the life-cycle of the equipment. Improvement in efficiency could be achieved by replacing, through attrition, motors that economically qualify with energy efficient motors. Few of the motors, when they do fail, qualify for economic replacement. In this study, no motors qualified for immediate replacement since the expected reduction in operating costs could not amortize the cost of a new motor in a reasonable length of time.

Standardization of motors and efficiency improvement through the application of capacitors and power factor controllers were considered and determined not to be cost effective at this time.

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INTRODUCTION

The purpose of this inventory and study was to develop a plan for reducing electrical energy consumption at Lone Star Army Ammunition Plant (LSAAP) through the use of properly sized and energy efficient electric motors. An inventory was to be conducted on all LSAAP electric motors rated one-quarter horsepower or greater. Pertinent motor data and application were to be recorded. The information compiled was to be used to determine where deficiencies exist and to develop a means for orderly elimination of those deficiencies. A comparison was to be made involving the applicability of energy efficient electric motors versus standard models at LSAAP. A determination was to be made relative to the value of standardizing electric motors for specific applications.

There are presently 3566 electric motors at LSAAP that have a rating of one-quarter horsepower or greater. Of these, 1299 are active and 2267 are inactive. These motors range in size up to 300 horsepower.

PROJECT PROCEDURE

During the engineering study to be made of the electric motors installed at Lone Star Army Ammunition Plant, the following steps were taken to develop a plan for reducing electrical energy through the use of properly sized and more efficient electric motors:

1. Perform an audit/inventory of all electric motors. The audit will include the recording of all currently installed motors one-quarter horsepower and over, by physical location, pertinent electrical data and application.
2. Investigate all motors 1/4 H.P. and over to determine capacity, voltage and phasing requirements in relationship to function performed.
3. Analyze data obtained and determine proper size and physical characteristics where deficiencies in existing motors are found.
4. Research commercial market for sources of energy efficient motors, obtain catalog, delivery and pricing information.
5. Analyze data to determine if it is in the best interest of economics and energy conservation to standardize electric motors for types of applications.
6. Enter raw motor data into computer for organizing and editing to facilitate further analysis and preparation of the final report.
7. Prepare tables and other support data for final report.

LSAAP HISTORY AND CURRENT STATUS

History

Lone Star Army Ammunition Plant (LSAAP) is a Government-Owned Contractor-Operated (GOCO) ammunition loading, assembly, and pack (L/A/P) facility that was built in the early 1940s to satisfy ordnance requirements generated by World War II. The facility is located in Northeast Texas, near Texarkana, Texas, and the main gate of the Plant is twelve (12) miles west of Texarkana, on U. S. Highway 82. LSAAP covers an area of about 24 square miles and there are more than 1172 buildings, structures, and facilities on the Installation. These buildings, structures, and facilities are widely dispersed because of explosive safety quantity-distance criteria, and there are 418 miles of roads and 38 miles of railroad on the reservation

The Lone Star Army Ammunition Plant (then Lone Star Ordnance Plant) was deactivated following World War II and combined with the adjoining Red River Army Depot to form Red River Arsenal. LSAAP remained in care-taker status under the administration of Red River Arsenal until May 1951 when the Plant was reactivated as an independent GOCO facility to satisfy ammunition requirements generated by the Korean Conflict.

There was a drastic reduction in ammunition production requirements following the termination of hostilities in Korea, but LSAAP was retained as an active GOCO installation. Most production activity during that period consisted of the demilitarization or modification of ammunition produced during the Korean Conflict, but this work sustained LSAAP's production base and facilitated the rapid expansion in production activity that was later required to satisfy ammunition requirements generated by military operations in Southeast Asia.

Ammunition production requirements have again declined since operations in Southeast Asia were terminated in 1973, but LSAAP's workload has been sustained to some extent by the design, construction, and proveout of new production facilities under the Production Base Modernization Program. Five projects for modernization of three additional facilities is nearing completion.

Since being awarded the 1951 contract for reactivation and operation of LSAAP, Day & Zimmermann, Inc. of Philadelphia, Pennsylvania, has been the operating contractor.

Mission

The mission of Lone Star Army Ammunition Plant is to load, assemble, and pack (L/A/P) ammunition and ammunition components. LSAAP, however, is a Government-Owned Contractor-Operated (GOCO) industrial facility, and all actions involving the expenditure of resources by the operating contractor at a GOCO plant must be approved, funded, and contractually directed on a case-by-case basis.

Area Functions and Current Status

As of 15 November 1982, there were 1172 buildings, structures, and facilities at LSAAP with a total floor space of 3,271,151 square feet, and located in 26 widely dispersed working areas on the reservation. Following are these work areas identified by name function and status as of above date:

Area A	Dunnage Mill and Lumber Storage	Active
Area B	Major Caliber Production Line	Active
Area C	Medium Caliber Production Line	Inactive
Area CC	Railroad Yard	Active
Area D	Inert Storage Area	Inactive
Area E	Medium Caliber Production Line	Project/Inactive
Area F	Minor Caliber Production Line	Inactive
Area G	Minor Caliber Production Line	Active
Area H	Inert Storage Area	Active
Area I	Administrative Area	Active
Area J	Fuse Load Line	Inactive
Area K	Fuse and Booster Load Line	Active
Area M	Fuse Load Line	Inactive
Area O	Renovation, Demel & Experimental Load Line	Inactive
Area P	Detonator Load Line	Project/Inactive
Area Q	Detonator Load Line	Active
Area R	Primer Load Line	Partially Active
Area S	Primer Load Line	Inactive
Area T	Explosive Storage Vaults	Active
Area U	Finished Ammo Storage	Active
Area V	Explosives and Raw Material Storage	Active
Area W	Finished Ammo Storage	Active
Area X	Sewage Treatment Plant	Active
Area XX	Text Area	Active
Area Y	Reservoir	Active
Area Z	Fire Pump Station	Active

A map of LSAAP is shown in figure 1.

MOTOR HISTORY

The production schedules and requirements have varied during the past 40 years, as has the number, sizes, types and application of the installed electric motors. Following World War II, Lone Star Army Ammunition Plant was deactivated and placed into caretaker status with all motors laid away. In May of 1951 the Plant was reactivated to support the Korean Conflict and all motors were taken out of layaway. LSAAP has remained in an active status since that date. At the present time we have 3 areas in total layaway and 8 areas in partial layaway. Current construction, modernization and expansion are adding

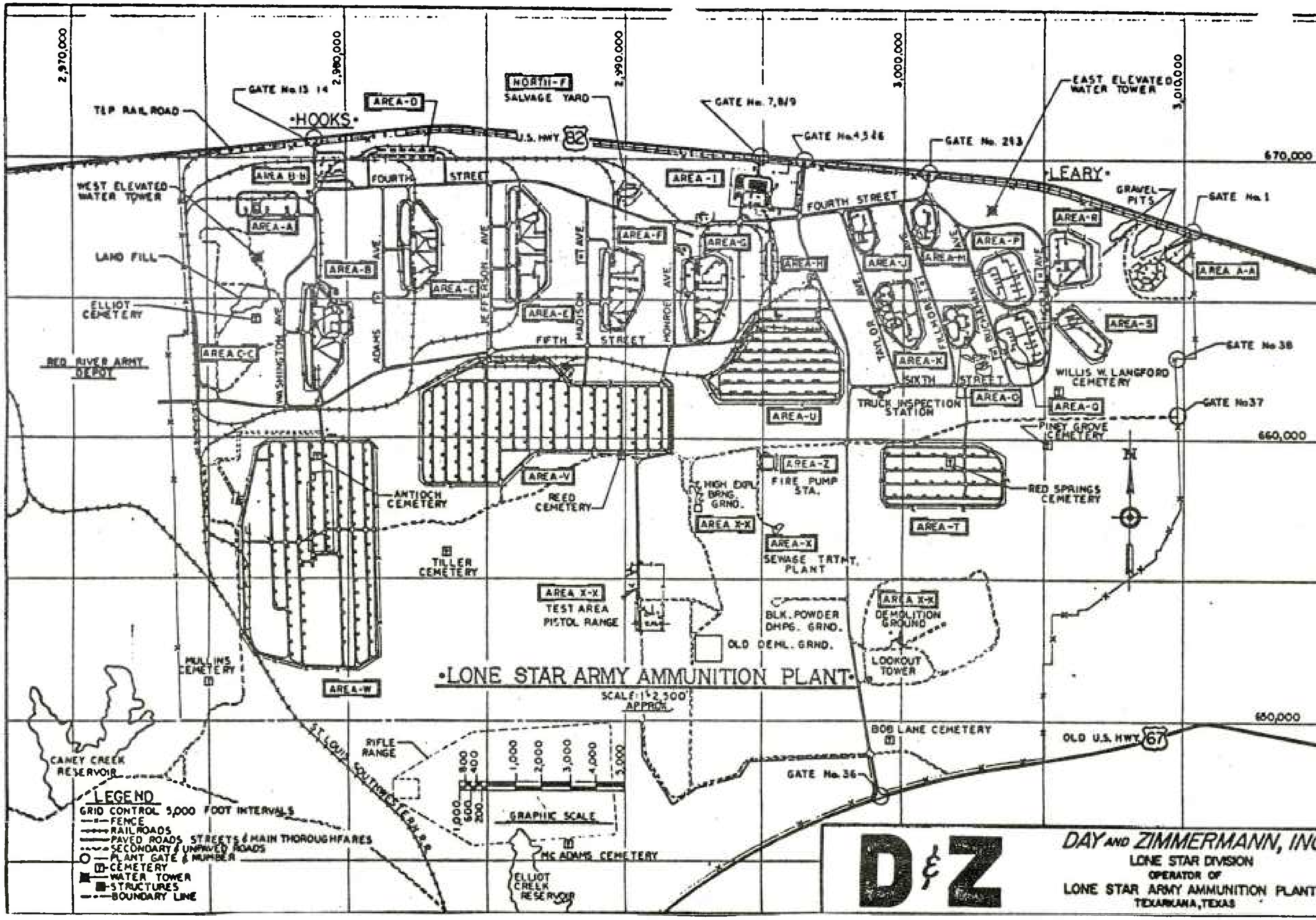

Figure 1. Map of Lone Star Army Ammunition Plant (dwg no. C-2910-2)

a large number of motors to the LSAAP motor inventory. LSAAP has had the capability of rewinding malfunctioning motors from fractional horsepower to 75 horsepower since the activation of LSAAP in 1940. Several thousand motors have passed through the rewind facilities during that period. This contributes to the fact that LSAAP has operational motors varying in age from new to 42 years.

MOTOR PROCUREMENT PROCEDURE

The procedure presently in use at LSAAP for procuring new and replacement motors is as follows:

When an engineer or maintenance representative becomes aware that a new or replacement motor is required a purchase requisition is prepared detailing the exact specifications. At that time the purchase requisition is reviewed by an electrical engineer for suitability of application. The purchase requisition is then processed through normal channels to the purchasing department.

The review by the electrical engineer will include such factors as energy efficiency, power factor, and service factor ratings.

LONE STAR ELECTRICAL SYSTEM

Electrical power for the operation of Lone Star Army Ammunition Plant is purchased through Red River Army Depot. Lone Star Army Ammunition Plant and Red River Army Depot are primarily serviced from Southwestern Electric Power Company's Substation (BANN) located 8 miles east of LSAAP on U.S. Highway 82. This Substation is an Automatically Switched, ring buss type, furnishing 3 phase 60 HZ 69 KV primary power to both locations. It has a capacity of 266,000 KVA and is supplied by SWEPCO's 138 KV transmission system.

Lone Star Army Ammunition Plant and Red River Army Depot are serviced from the BANN substation by a single 69 KV shielded transmission line with feeder transmission lines terminating at a substation at each location. The substation located at LSAAP consists of 2 each matched main 3750 KVA, forced air cooled and automatically switched transformers plus 1 each 5000 KVA voltage regulator which are owned and maintained by Southwestern Electric Power Company. This gives the substation a total capacity of 10,000 KVA.

The following services are available at most major areas: 120/240 60 HZ single phase, 440 V 3Ø with special service of 208 3Ø, 220 3Ø available where required.

ALTERNATIVES FOR IMPROVING ELECTRIC MOTOR EFFICIENCY

The objective of this study effort is to develop a plan for reducing electrical energy consumption at Lone Star Army Ammunition Plant (LSAAP) through the use of properly sized and energy efficient electric motors. That objective, however, implies that replacement of the existing motors at LSAAP with new energy efficient motors and reducing the horsepower ratings of the replacement motors (when applicable) are the only methodologies available for improving electrical power utilization efficiency. That is not the case. Electrical energy can also be conserved by installing energy efficiency improvement devices such as power factor connection controllers on existing motors, by utilizing higher speed motors in some instances, by installing motors specifically designed for each application, and by improving the mechanical efficiency of the driven equipment.

Energy Efficient Motors

Most major manufacturers are now marketing "energy efficient" electric motors, but this generic term was coined in December 1975 when the Century Electric Division of Gould Incorporated started publicizing a new line of more efficient electric motors called the "E Plus" series. Westinghouse Electric Corporation then introduced the MAC II line of "high efficiency" motors, and other manufacturers were soon marketing their electric motors on the basis of energy efficiency.

The ironic part of this new trend in electric motor design, however, was that it was basically a technological retreat. Electric motors manufactured during the 1930s were highly efficient, but like most metal working industries, the motor manufacturers eagerly adopted the postwar industrial methodology of Value Engineering - a systematic approach to engineering the initial cost out of products by changing materials and/or manufacturing processes. They got a big break when wire enamels were developed that could withstand much higher temperatures, which meant that electrical motors could run hotter, and that, in turn, meant that thinner copper wiring could be utilized in motor windings. The additional heat produced by essentially the same current passing through smaller-diameter wiring degraded motor efficiency, but in those days energy was cheap. Magnetic cores were also whittled down, and what finally evolved were not only cheaper electric motors but more compact ones that equipment designers found increasingly attractive.

The new lines of "energy efficient" motors now being marketed operate up to 50°F cooler than standard electric motors with the same output rating, and that obviously improves efficiency. This increased efficiency has been achieved, however, by increasing the diameter of the wiring utilized in motor windings and the amount of steel utilized in magnetic cores. The new "energy efficient" electric motors are, therefore, generally larger and heavier than standard motors of the same output rating, and energy efficient motors cost about 25% more than standard motors.

It should also be noted that the replacement of smaller motors with energy efficient motors will achieve a much greater improvement in efficiency than is the case with larger motors. For example: An energy efficient 3 horsepower motor will be about 4.5% more efficient than the industry average for a standard 3 horsepower motor. The efficiency of a 25 horsepower energy efficient motor, however, is less than 2% greater than the industry average for a standard 25 horsepower motor.

Reduction in Horsepower Ratings

Electric motors are normally designed to achieve maximum efficiency when operating at rated output, and they are much less efficient when operated at lower loads. Most electric motors, however, are operated at far less than rated output because of overly conservative specifications set by machine designers, vendors, and/or maintenance supervisors. This overdesign wastes electrical power, but in most instances it is impossible to establish the degree of this over-design at the operating level.

Energy Efficiency Improvement Devices

Most electric motors are of the induction type, and the inductive reactance of these motors causes the current cycle to lag the voltage cycle. This causes the motor to draw more electrical power from the utility line than can be utilized to perform useful work, and the ratio between these two values is designated as the Power Factor. For maximum efficiency, the Power Factor must be maintained as near unity as possible, and this can be achieved by installing capacitors or over-excited synchronous motor to provide capacitive reactance.

A more sophisticated solution to the power factor problem has been developed by NASA (Nola Patent) and more than forty manufacturers are now marketing power factor controllers under NASA license. These devices are designed to improve the power factor by sensing the load imposed on the motor and reducing the applied voltage so that the motor still draws essentially full load current at full load power factor when operating at less than rated output.

These power factor controllers were originally developed for use with single phase AC motors, and initial attempts to apply this concept to 3 phase AC motors have been unsuccessful due to serious instability problems (i.e. Violent vibration). Several manufacturers now claim that they have resolved the instability problem, but these second-generation controllers have not yet been accepted by industrial users.

Other Alternatives

The utilization of higher speed motors would conserve electrical power in some instances, and the installation of motors specifically designed for each application would presumably eliminate the waste of electrical power stemming from over-design.

Motor Replacement

Four of the above alternatives for reducing electrical power consumption at LSAAP involve the replacement of existing motors with motors having superior operating characteristics. With the possible exception of interface problems caused by the larger envelopes and increased weights of energy efficient motors, installation of more efficient electric motors would be quite simple. Projecting the improvement in electrical utilization efficiency achieved by these replacements is not. The efficiencies of electric motors vary by motor type and size, by manufacturer, by date of manufacture, by location and service, by duty cycle, and by level of maintenance. Very few manufacturers provide efficiency data in their sales catalogs, and those that do only provide this data for full load operation. It is, therefore, impossible to accurately compare electric motor efficiencies without actual operating data.

Energy efficient electric motors cost about 25% more than standard motors with the same output rating. High speed motors designed for specific applications are even more expensive. Vendors claim that these higher initial costs will be quickly amortized by the savings achieved, but these claims are invariably based on the assumption that the new electric motors will be operated continuously at full-rated output. That is not the case in most industrial applications, so these vendor claims are generally inflated.

Capacitors, Synchronous Motor, etc.

Installation of capacitors and/or over-excited synchronous motors (synchronous capacitors) has been the standard method of improving the power factor in AC distribution systems for many years. This methodology, however, has been implemented at LSAAP. There are currently twenty large air compressors at this Plant which are driven by synchronous motors, and the LSAAP power factor is generally about 99.7%.

Installation of the NASA (Nola Patent) power factor controllers on existing motors at LSAAP which normally operate at less than rated output would conserve electrical energy, but these devices cost up to $1400 per motor (The average cost is about $850.) These devices are a recent technological development, and the practical application of this technology to three-phase motors has yet to be demonstrated in the field. This suggests that it would be premature to install these devices at LSAAP at the present time.

Summary

There are at least six methodologies available for reducing electrical consumption at Lone Star Army Ammunition, but only highly empirical procedures exist for projecting the energy savings which would accrue from these alternatives. In fact, a full Life Cycle Cost Analysis would have to be conducted on each existing motor to establish if the additional cost of implementing any of these methodologies could be justified on an economic basis. This suggests that it would be more cost-effective to conduct these Life Cycle Cost Analysis on a case-by-case basis as the existing motors are replaced at LSAAP than attempt to justify the replacement of all existing motors at this Plant under a single plan.

LSAAP MOTOR INFORMATION

For this study, the following motor data was compiled: Location, function, horsepower, nameplate voltage, nameplate amperage, speed, phase, estimated annual hours of operation, and approximate annual cost of electricity to operate each size of motor. This data was used to determine the technical and economical potential for motor replacement or other actions which would result in reduced electrical demand.

All motor information was gathered and recorded by Facilities Engineering personnel. The reported annual hours of operation for the active motors was provided by Plant personnel familiar with normal duty cycle of each motor. Because these values are estimates, there may be some discrepancies; however, these estimates should be sufficiently close to have an adequate level of confidence in the results.

Annual Cost of Operation for Electrical Motors, based on SWEPCO's average October 82 billing rate of $0.051/KWH* and operating at rated output on an around-the-clock basis 365 days/year.

= (Horsepower rating) ($490.12)

To pro-rate costs for motors which operate less than 8760 hours/year, multiply the above cost by the following factor:

$$\frac{\text{(annual operating hours)}}{\text{8760 hrs}}$$

For example - The annual electrical cost for a 10 horsepower motor operated on a 1-8-5 shift basis would be:

$$\frac{\text{(10HP)(\$490.12)(252 duty days/yr)(8 hrs/day)}}{\text{8760 hrs/yr}} = \underline{\$1127.95}$$

If that motor was only operating with a 50% duty cycle, the annual cost would be 0.5 ($1127.95) = $563.97, etc.

ECONOMIC EVALUATION OF ELECTRIC MOTOR REPLACEMENT

The various methodologies for reducing electrical power consumption at Lone Star Army Ammunition Plant (LSAAP) were discussed under the Alternatives for Improving Electric Motor Efficiency, and it is apparent that the greatest improvement in utilization efficiency would be achieved by replacing the existing electric motors at this Plant with energy efficient motors. Utilizing high-speed motors, installing power factor controllers on the existing motors, switching to smaller motors, and utilizing motors which are specifically designed for each application were also considered, but it was concluded that these alternatives are generally

* Economic analysis in this report is based on 1982 dollars.

more expensive and provide less improvement in efficiency than a motor change.

The purchase price differential between standard and energy efficient electric motors is dependent on motor output rating, frame size, electrical input (i.e. 120 volt single phase, 240/480 volt three phase, etc), motor speed, and type of service. That cost differential tends to increase with output rating, but it should be noted that the improvement in efficiency achieved by switching to energy efficient motors tends to decrease as horsepower ratings increase.

As noted in the discussion under Alternatives for Improving Electric Motor Efficiency, each of the 3566 existing motors at LSAAP would have to be evaluated on an individual basis for an accurate projection of the improvement in electrical utilization efficiency that would be achieved at this Plant through the use of energy efficient motors. The results of that monumental analysis effort, however, would still be highly empirical as actual performance data do not exist for a valid comparison of motor efficiencies under all operating conditions.

The variables considered in this Economic Analysis have, therefore, been reduced to the minimum required for a reasonably accurate assessment of the potential for replacing the existing motors at this Plant with energy efficient motors. The following assumptions have been made to facilitate that reduction:

1. That all existing motors at this Plant are totally enclosed, fan-cooled, and explosion-proof (class II, Division 2, Groups E, F, or G.)

2. That these existing motors are all powered by three-phase 240/480 volt alternating current.

3. That these existing motors will be operated on a 1-8-5 shift basis, 400 minutes per shift, for 252 days per year.

4. That these existing motors will be operated at full-rated output with a 50% duty cycle during duty days.

5. That the energy efficient motors utilized to replace these existing motors will have these same design characteristics and be operated under the same conditions.

The current Government-approved rate schedule for electrical service rendered to the Lone Star Army Ammunition Plant/Red River Army Depot industrial complex is based on a flat demand charge of $4.25/KW, a flat usage charge of $0.0054/KWH, plus a Fuel Adjustment Charge which during October 82 was $0.02789/KWH. The average cost of electrical energy consumed at LSAAP during October 1982 was about $0.051/KWH. The electrical cost utilized in this Economic Analysis will, therefore, be $0.051/KWH.

Table 4 provides a summary, by horsepower rating, of the percentage increases in efficiency which would be achieved by replacing existing motors with energy efficient motors; the percentage reductions in electrical power consumptions that would result from these increases in utilization efficiency; and the projected reductions in annual electrical costs which would be achieved by these reductions in usage at current rates.

Two alternative methods of replacing the existing motors at LSAAP with energy efficient motors have been considered in this study. The simplest procedure (Case I) would be replace the existing motors with energy efficient motors as they fail in service. The advantage of this method is that only the differential price of the energy efficient motor would be an investment cost since the procurement and installation of a replacement motor would be required in any case. The other option is to replace all of the existing motors at this Plant with energy efficient motors within a relatively short time frame under one project. The advantage of this method is that all existing motors at LSAAP would be replaced with energy efficient motors on a programmed basis. (Replacement of the existing motors by attrition would take many years, and there can be no assurance the effort would ever be completed on a Plant-wide basis.) The disadvantage of this method, however, is that the full purchase price of the energy efficient motors plus installation costs would be an investment cost, as the existing motors would still be operating satisfactorily at the time of removal.

The differential price, by horsepower rating, under Case I--the purchase price plus installation cost, by horsepower rating, under Case 2--and the simple payback periods in years for the annual savings in electrical costs to amortize these investment costs are presented in Table 4 . The maximum pay-back period for projects submitted under the Quick Return on Investment Program (QRIP) is two years, and the maximum payback period for other investment programs utilizing production funds is generally three years. For purposes of this study, it has been assumed that the maximum permissable payback period for replacement of an existing motor with an energy efficient motor is three years.

The Energy Conservation and Management (ECAM) Program was established in FY1982 to support the implementation of energy conservation measures at Government-Owned Contractor-Operated (GOCO) industrial facilities. ECAM projects are submitted as Subproject 51 under the annual Production Support and Equipment Replacement (PS&ER) projects for GOCO installations, and the ECAM Program utilizes production funds. The criteria for submission of ECAM projects, however, are identical to the criteria prescribed for Energy Conservation Investment Program (ECIP) projects. Those criteria require a discounted benefit to cost ratio greater than one and a ratio of projective annual MBTU savings to thousands of dollars at investment cost (E/C ratio) greater than 13 (FY84 criteria). The four-year planning cycle utilized for the programming of ECAM projects is a major constant on the implementation of energy conservation actions of the magnitude envisioned in this study, and that problem is compounded by the existing policy that PS&ER funds (and that includes ECAM funding) can only be utilized to support current production requirements. It is, therefore, most unlikely that replacement of the existing electric motors at LSAAP with energy efficient motors could be accomplished under the ECAM Program.

The payback periods listed under Table 4 for replacement of the existing electric motors at LSAAP with energy efficient motors on an attrition basis (Case I) indicate that this procedure would be cost-effective for motors with an output of 5 horsepower, and above. The payback periods for motors of less than 5 horsepower under Case I, however, are all greater than three years, and it will be impossible to justify replacement of these smaller motors with energy efficient motors on an economic basis.

The payback periods listed under Table 4 for replacement of the existing electric motors at LSAAP with energy efficient motors within a relatively short time frame under one project (Case 2) range from 18.9 years to 81.2 years. The useful service life of an electric motor, however, is only ten years, so it will be impossible to justify the replacement of all existing motors at this Plant with energy efficient motors on an economic basis.

MOTOR DEFICIENCIES

Very few cases of motor deficiencies were discovered during this survey. Most cases were excessive loading due to the applied voltage being different than the indicated nameplate voltage. Another reason for an indication of excessive loading is the service factor rating most motors are subject to, which permits overloads not to exceed 35% depending on the motor rating and type.

Out of 1299 active motors, 12 indicated an overloaded status, 6 were corrected on the spot by minor voltage changes and mechanical adjustments 6 each of five (5) horsepower or greater are scheduled for repair or replacement.

STANDARDIZATION OF MOTORS

A major benefit of standardizing motor types and sizes where possibile would be the rapid replacement capibility of problem motors by having inactive motors of the same description on-hand. This would reduce the problem of long delivering periods. Price discounts that Vendors offer when a sizeable amount of identical motors are purchased is another benefit to be considered.

The main limitation to standardizing motors at LSAAP is the variation of application of motors due to the different types of ammunition load, assemble, and pack operation. This survey indicates that there are very few common types of motor application. The requirement for explosion-proof construction for approximately 75% of the motors located on the production lines reduces the potential for standardization.

CONCLUSIONS

1. Current practices at Lone Star Army Ammunition Plant (LSAAP) for replacement of electric motors are cost effective and energy efficient over the life cycle of the equipment.

2. The various alternatives for reducing electrical power consumption at LSAAP by improving electric motor efficiency demonstrated that the greatest improvement in utilization efficiency could be achieved by replacing, through attrition, the existing electric motors of 5 horsepower and above with energy efficient motors.

3. Of the motors inventoried, few qualify for economic replacement when the present motor fails. No motors qualified for immediate replacement since the expected reduction in operating costs could not amortize the cost of a new motor in any reasonable length of time.

4. Standardization of motors and efficiency improvement through application of capacitors and power factor controllers were considered and found not to be cost effective at this time.

RECOMMENDATIONS

1. Actual energy cost savings and maintenance savings must provide adequate economic advantage to justify motor replacement for standardization purposes. Therefore, overall standardization of motors at LSAAP is not recommended.

2. Motors that fail should be analyzed on a case-by-case basis to determine if replacement by energy efficient motors is cost effective.

Table 1. Summary of annual hours of operation of active motors

No. of hours	No. of motors	% of total
0-99	42	3.2
100-500	712	54.8
501-1000	341	26.3
1001-2000	155	11.9
2001-up	49	3.8
TOTAL	1299	100.0

Table 2. Summary of active, and inactive motors identified by horsepower

Horsepower rating	Active motors		Inactive motors		Active and inactive motors	
	No.	% of total active	No.	% of total inactive	No.	% of total
0.25	168	12.9	223	9.8	391	11.0
0.33	116	8.9	129	5.7	245	6.9
0.5	249	19.2	374	16.5	623	17.5
0.75	116	8.9	176	7.8	292	8.2
1.0	127	9.8	193	8.5	320	9.0
1.5	55	4.2	522	23.0	577	16.2
2.0	75	5.8	125	5.5	200	5.6
3.0	96	7.4	129	5.7	225	6.3
5.0	151	11.6	167	7.4	318	8.9
7.5	47	3.6	94	4.2	141	3.9
10	49	3.8	53	2.3	102	2.9
15	6	0.5	35	1.5	41	1.1
20	5	0.4	7	0.3	12	0.3
25	5	0.4	5	0.2	10	0.3
30	17	1.3	5	0.2	22	0.6
40	1	0.1	4	0.2	5	0.1
50	2	0.2	5	0.2	7	0.2
75	7	0.5	8	0.4	15	0.4
100	3	0.2	3	0.1	6	0.2
125	3	0.2	0	0.0	3	0.1
150	1	0.1	2	0.1	3	0.1
200	0	0.0	1	0.1	1	0.0
300	0	0.0	7	0.3	7	0.2
TOTALS	1,299	100.0	2,267	100.0	3,566	100.0

Table 3. Summary of active, inactive, and total by location

Area	Active motors No.	Active motors % of total active	Inactive motors No.	Inactive motors % of total inactive	Active and inactive motors No.	Active and inactive motors % of total
A	7	0.5	0	0.0	7	0.2
B	155	11.9	0	0.0	155	4.4
C	0	0.0	181	8.0	181	5.1
D	0	0.0	489	21.6	489	13.7
E	0	0.0	896	39.5	896	25.1
F	0	0.0	168	7.4	168	4.7
G	321	24.7	0	0.0	321	9.0
H	20	1.5	0	0.0	20	0.6
I	311	24.0	0	0.0	311	8.7
J	0	0.0	57	2.5	57	1.6
K	197	15.2	0	0.0	197	5.5
M	0	0.0	42	1.8	42	1.2
0	0	0.0	100	4.4	100	2.8
P	0	0.0	326	14.4	326	9.1
Q	104	8.0	0	0.0	104	2.9
R	184	14.2	0	0.0	184	5.2
S	0	0.0	8	0.4	8	0.2
TOTALS	1,299	100.0	2,267	100.0	3,566	100.0

Table 4. Summary of annual cost (electricity) and pay-back period of motor changes

				Case 1		Case 2	
Horsepower rating	Improvement efficiency (%)	Reduction in energy usage (%)	Reduction in energy cost ($)	Differential purchase cost ($)	Payback period (yrs)	Purchase cost plus installation ($)	Payback period (yrs)
0.25	8	13.0	2.56	12	4.68	260	21.6
0.33	8	13.0	3.42	18	5.26	278	81.2
0.5	8	13.0	5.12	21	4.10	291	56.8
0.75	8	13.0	7.70	28	3.63	308	40.0
1.0	8	13.0	10.26	45	4.38	335	32.6
1.5	5	7.7	9.12	46	5.04	350	38.3
2.0	5	7.7	12.16	70	5.75	384	31.5
3.0	4	5.5	13.03	70	5.37	430	33.0
5.0	4	5.5	21.71	42	1.93	510	23.4
7.5	3	3.9	23.09	46	1.99	626	27.1
10.0	3	3.9	30.79	60	1.94	734	23.8
15.0	3	3.8	45.00	76	1.68	990	22.0
20.0	3	3.8	60.00	96	1.60	1176	19.6
25.0	3	3.6	71.00	168	2.36	1426	20.0
30.0	3	3.6	85.27	148	1.73	1620	18.9
40.0	2	2.4	75.79	106	1.39	2160	28.4
50.0	2	2.4	94.74	135	1.42	2489	26.2
75.0	2	2.4	142.11	109	0.76	3669	25.8
100.0	2	2.4	189.48	162	0.85	4472	23.6
125.0	2	2.3	226.98	127	0.56	5733	25.2
150.0	1	1.1	130.27	165	1.26	6563	50.3
200.0	1	1.1	173.69	342	1.96	9214	53.0

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